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EVALUATION OF THE MECHANICAL PROPERTIES OF PHOBOS' REGOLITH

A. V. Kozenko

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16. Abstract

Slopes and heights in craters and grooves which appear to be overlain with regolith make it possible to set lower limits for regolith strength. The mechanical properties for this material are set at $c = 0.001\text{-}0.07\ N/cm^2$, $\varphi = 5\text{-}30°$.

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EVALUATION OF THE MECHANICAL PROPERTIES OF PHOBOS' REGOLITH

A. V. Kozenko

Photometric, polarimetric, and radiometric data indicate that Phobos' surface is covered with fine regolith formed due to impact with the ground [2]. Its mechanical properties can be pre-determined on the basis of the results of studying the morphology of the satellite's craters and grooves. We know that the transverse profile of grooves is smooth and that groove walls are usually rather flat, with less than a 10° slope. Only the largest grooves near the crater Stickney have slopes as high as 30°. Furrows are no more than 100 m deep [11]. In addition, preliminary photogrammetric evaluations indicate that the average depth/diameter ratio for young craters is close to 0.2 [10]. Large craters have diameters measured in kilometers (the diameter of the largest crater, Stickney, equals 8 km). Therefore, rather deep bowl-shaped craters in the equatorial region have sides curved more than 40-50° [4]. According to A. T. Bazilevskiy's evaluations, maximum slope curvature on the inner sides reaches 50-60° [6]. Crater sides must consist of fine-grain and large-chunk material with a slope equal to the limit permissible for the soil's given mechanical parameters.** /155*

The soil's mechanical properties are a function of the characteristics of the interaction between particles -- friction and autogenesis -- quantified by cohesion and the angle of

*Numbers in the margin indicate pagination of the foreign text.

**First, the regolith itself may possibly constitute only the top of the slope, since the regolith's thickness is measured in hundreds of meters. Second, because Phobos is not a sphere, evaluation of slope curvature has an indeterminateness of 5-10°, since it was conducted on the basis of shadows cast and on the assumption that the satellite is a sphere.

internal friction respectively. Consequently, different combinations of cohesion and friction parameters may provide observable values for slope curvature. This article presents corresponding evaluations of these parameters in terms of order of magnitude.

Several approximation techniques for calculating slope stability on the basis of given mechanical soil properties -- internal friction angle, cohesion, and volumetric weight -- are used in soil mechanics to determine maximum slope curvature at a fixed height. K. Tertsagi's ratio is used for this purpose [3]: /156

$$c/\rho g = H/N, \tag{1}$$

where H is critical slope height; c, soil cohesion; ρ, soil density; g, gravitational acceleration; N, a factor dependent on internal friction angle φ and slope β and determined from Terzagi's curve ([3], fig. 45).

In this case, the limit equilibrium for slope from a uniform material lying on a uniform base is established. It is assumed that a slope fails due to formation of a round-cylinder sliding surface crossing the vertex and base of the slope. Then, assigning $N(\varphi,\beta)$, one can obtain the lower limit for $c/\rho g$, and, knowing ρ and g, find cohesion c, which, together with internal friction angle φ, gives the total characteristic for the soil's mechanical properties.

The resulting mechanical properties may be used to determine the soil's bearing capacity p. In case of local shear, i.e. when the soil is packed only indirectly under the load-imposing area, for a long band of width 2b, it is determined near the soil surface according to [3], with the following ratio:

$$p = \frac{2}{3} c\chi_c' + \rho g b \chi_\gamma' + \rho g t_g \chi_p', \tag{2}$$

where t_g is band width beneath the soil surface; χ_c', χ_p', and χ_γ' are bearing capacity factors, which are functions of φ and are adjusted to Terzagi's curve [3, fig. 38] also in R. Scott [9]. Since local shear at $t_g=0$ gives the lower boundary for bearing capacity, the following ratio is used for calculations:

$$p=\frac{2}{3}c\chi_c'+\rho g b\chi_\gamma'. \tag{3}$$

Free fall accelerations differ substantially for various bodies in the Solar System (for the Moon, $g\sim162$ cm/sec^2; for Phobos, $g\sim0.5$ cm/sec^2). Therefore, following L. Jaffe [8], we can conveniently introduce mass bearing capacity $p_m=p/g$. Then ratio (3) takes the form

$$p_m/\rho=2c\chi_c'/3\rho g+b\chi_\gamma'. \tag{4}$$

Calculations were performed for Phobos for data on the morphology of craters and grooves. Average regolith density on the surface was set on the order of 1 g/cm^3; gravitational acceleration, about 0.5 cm/sec^2 (for details, see [1]).

On the basis of data on craters, soil cohesion is evaluated at $c_{kr}\approx0.07$-0.03 N/cm^2; on the basis of data on grooves, at $c_b\approx0.005$-0.001 N/cm^2. The internal friction angle φ was set at 5-30°. Mass bearing capacities were respectively set on the order of 100 and 5 kg/cm^2 or 0.5 and 0.025 N/cm^2. These values should be considered somewhat underestimated.

The discrepancy in mechanical properties of Phobos' soil surface in different structural formations -- craters and grooves -- is noteworthy. At this point it is not entirely understood. These soil parameters are also somewhat lower than similar parameters for the Moon's soil: $\varphi\approx10$-$45°$, $c=0.01$-0.04 N/cm^2, and bearing capacity about 3 N/cm^2 [7], although the adhesion of lunar soil not shown in the photometric target of Surveyor 6 is calculated at 0.001-0.01 N/cm^2 [5].

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